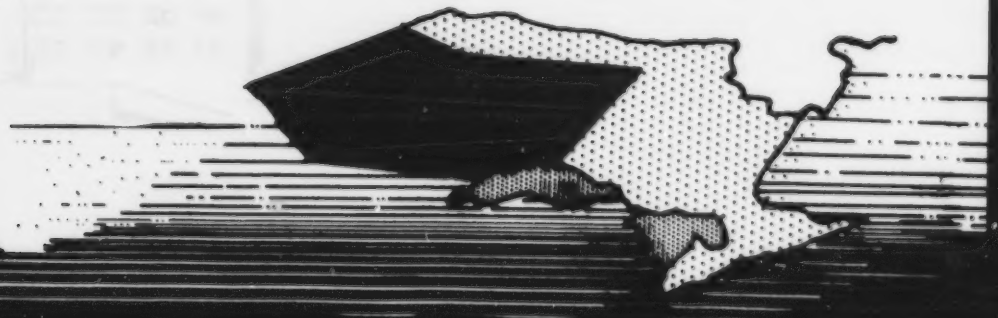

Ministry of Natural Resources
Ontario

NORTHWESTERN ONTARIO FOREST TECHNOLOGY DEVELOPMENT UNIT

STAND STRUCTURE, SPECIES COMPOSITION, AND GROWTH OF THE BOREAL MIXEDWOOD FOREST IN NORTHERN ONTARIO:

A Comparison of Natural Stands and Plantations

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STAND STRUCTURE, SPECIES COMPOSITION, AND GROWTH OF THE BOREAL MIXEDWOOD FOREST IN NORTHERN ONTARIO:

A Comparison of Natural Stands and Plantations

BY

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ABSTRACT

Morris, D.M., M.K. Rose, and G.B. MacDonald. 1988. Stand structure, species composition, and growth of the boreal mixedwood forest in Northern Ontario: A comparison of natural stands and plantations. OMNR, NWOFTDU, Technical Report #22. 21 p.

Key Words: Boreal mixedwood, stand structure, species composition, growth, natural stands, plantations.

The objective of this paper was to provide awareness to others about the complexities of the boreal mixedwood forest in Northern Ontario. As we enter a new era of increasingly intensive forest management on mixedwood sites, it is essential that the forest manager gain a better understanding of stand dynamics. This understanding includes forest development in terms of growth, changes in species composition, and stand structure.

The data presented here were part of a long term study which is currently attempting to model forest growth and development of mixedwood stands. Both mensurational measurements and stem analysis were carried out in eight circular plots (1/8 of a hectare in size) in the North Central Region. Four plots were located in natural stands (ranging from 45 yrs. to 85 yrs.) with the other four in spruce plantations (ranging from 15 yrs. to 25 yrs.). An additional source of mensurational data detailing early development of natural stands was obtained from a discussion paper presented by N.F. Lyon in 1974 at the Sixth Annual Lakehead University Forest Association Symposium entitled **"The Future Forest"**.

A series of figures compared the changes over time in species composition, stand structure, and growth rate for natural stands and plantations on typical mixedwood sites. This comparison identified a number of important differences in stand development which are important in the management of these stands. A positive note to current harvesting and mechanical site preparation methods is the virtual lack of advanced balsam fir regeneration present in plantations. Mature balsam fir is particularly susceptible to spruce budworm damage and eventual mortality. Therefore, as these plantations develop, the risk of spruce budworm infestation and subsequent wildfires may be reduced, while at the same time containing a greater proportion of the desired crop species. On the negative side, it was illustrated that these plantations have more intensive competition both within and between species, resulting in the greater mortality rates and lower relative height growth rates. The spruce volume increment becomes a significant portion of the overall stand volume at age 15-20 years. Reduction of this lag-time could significantly decrease the rotation age of the crop species.

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STAND STRUCTURE, SPECIES COMPOSITION AND GROWTH OF THE BOREAL MIXEDWOOD FOREST IN NORTHERN ONTARIO: A Comparison of Natural Stands and Plantations

D.M. Morris[1], M.K. Rose[2], and G.B. MacDonald[3]

INTRODUCTION

The boreal mixedwood forest by definition includes sites that support or could support, good growth of the five main component species. These species include white spruce (Picea glauca [Moench] Voss), black spruce (Picea mariana [Mill.] B.S.P.), balsam fir (Abies balsamifera [L.] Mill.), trembling aspen (Populus tremuloides Michsx), and white birch (Betula papyrifera Marsh.). Essentially, sites excluded under this definition are wet, poorly drained lowlands, dry sand plains, and excessively drained shallow soils on rocky ridges (McClain, 1981). Due to the wide range of site conditions that mixedwoods occupy and their dynamic nature, species composition varies considerably.

Overall, it has been estimated that nearly 50% of Ontario's productive forest land lies within the boreal mixedwood forest (Weingartner and Basham, 1979) and supports perhaps as much as 46% of Ontario's primary growing stock (Dixon, 1963). Furthermore, Ketcheson (1981) suggested that the annual harvest from mixedwood forests could be as much as 26% of the total harvest from crown lands. Clearly, the boreal mixedwood forest is economically

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important to Ontario's forest industry and, therefore, deserves greater attention by foresters to manage this forest type as a whole.

As we enter this new era of increasingly intensive forest management on mixedwood sites, it is essential that the forest manager gains a better understanding of stand dynamics. This understanding includes forest development in terms of growth, changes in species composition, and stand structure. The purpose of this paper is to illustrate these changes over time for both natural mixedwoods and plantations established on mixedwood sites.

The majority of the information presented in this paper was tabulated from an extensive data base collected by staff at the Northern Forest Research Unit during a period from 1982 to 1986. The mensurational and stem analysis data reported on are from 8 circular plots (1/8 of a hectare in size) in the North Central Region of Ontario (Table 1). Four plots were located in natural stands (ranging from 45 yrs. to 85 yrs.) with other four in spruce plantations (ranging from 15 yrs. to 25 yrs.). An additional source of mensurational data detailing early development of natural stands was taken from discussion paper by N.F. Lyon (Research Supervisor, retired - Northern Forest Research Unit) presented at the Sixth Annual Lakehead University Forest Association Symposium entitled **"The Future Forest"** (Lyon, 1974). This data concentrated on development of species composition during the first 18 years after disturbance.

Table 1. Plot Summaries of Site Description.

Plot No.	Stand Type	Location (Lat./Long.)	Mean Age	Age Range	Number of Stems	FEC CLASSIFICATION* Vegetation Type	Site Type	Soil Text.	Surficial Geology
					... per ha ...				
1	Nat.	49°27'N 90°14'W	45	21-75	3486	Fb-Hdw (V14)	Fresh (S3)	Loam	Basal Till
2	Nat.	50°27'N 87°05'W	60	27-86	1793	At-Sw (V7)	Fresh (S5)	Silty Clay	Basal Till
3	Nat.	48°25'N 90°08'W	65	27-90	1783	Fb-Hdw (V15)	Fresh (S3)	Loam	Basal Till
4	Nat.	48°37'N 90°13'W	85	32-146	1361	Sw-Hdw (V16)	Fresh (S3)	Sandy Loam	Basal Till
5	Plant.	49°52'N 87°01'W	15	11-61	6310	At-Sb (V10)	Fresh (S3)	Sandy Loam	Outwash
6	Plant.	49°52'N 87°01'W	15	8-64	5602	At-Sw (V7)	Fresh (S3)	Loamy Sand	Outwash
7	Plant.	49°33'N 88°00'W	25	16-36	2674	Sb-Hdw (V19)	Fresh (S3)	Sandy Loam	Outwash
8	Plant.	49°33'N 88°00'W	25	18-31	2960	Sb-Hdw (V19)	Fresh ($S4^1$)	Silt Loam	Outwash

* - according to "Field Guide to Forest Ecosystem Classification of the North Central Region, Site Regions 3W, 4W." (Sims et al 1987).

SPECIES COMPOSITION

Figures 1 and 2 illustrate the changes of species composition over time for both the natural stand and plantation.

Natural Stand Development

In general, a distinct feature of the natural mixedwood stand is the large component of balsam fir present during early stand development (Lyon, 1974). This fir component represents over 50% of the total number of stems. The majority of the remaining stems are hardwood, with less than 5% of the stand being comprised of spruce (Figure 1).

Notable changes occur over time for all species. The balsam fir seedlings have developed under the old stand canopy and, therefore, can be classed as "shade trees". These trees, once released, are subjected to high intensities of light. As a result, high mortality exists until the stand reaches an age of 35. After this point, the fir population remains stable as the remaining trees adjust to the new light regime (Figure 1).

A high mortality rate also exists for the intolerant hardwoods. Intense inter-specific competition between the hardwood root suckers continues until age 55. Over 95% of the remaining hardwood stems can be classed as dominants of co-dominants (Figure 2) and make up almost 50% of the overstory (Figure 3).

The spruce component, conversely to that of the fir and hardwood, steadily increases to approximately 1800 stems/ha by age 35. At this point, the stand has developed a tiered canopy structure (dominant/co-dominant/suppressed). A large portion of the "recruited" spruce fall into the suppressed category. These trees slowly succumb to competition over the next 50 years or less than 200 stems/ha (Figure 1).

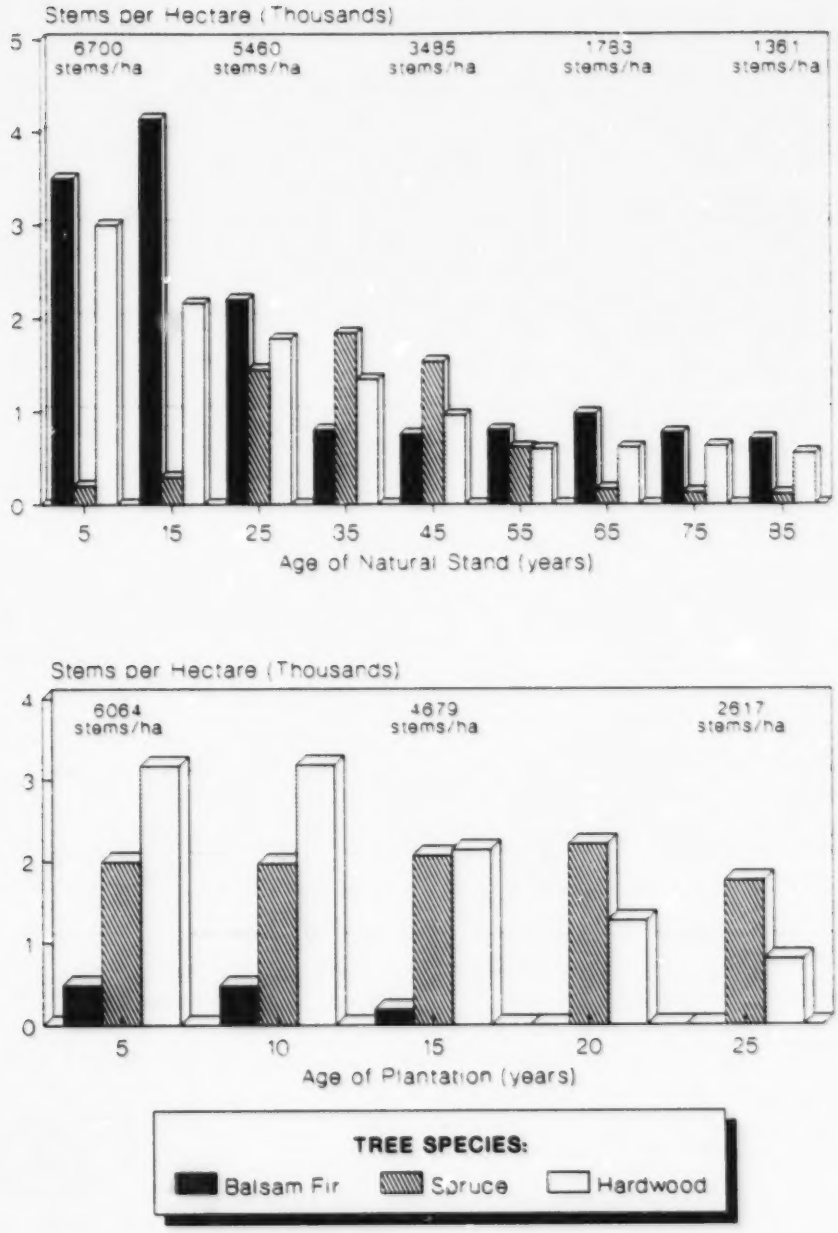

Figure 1. Comparison of species composition for natural mixedwood stands with plantations established on mixedwood sites.

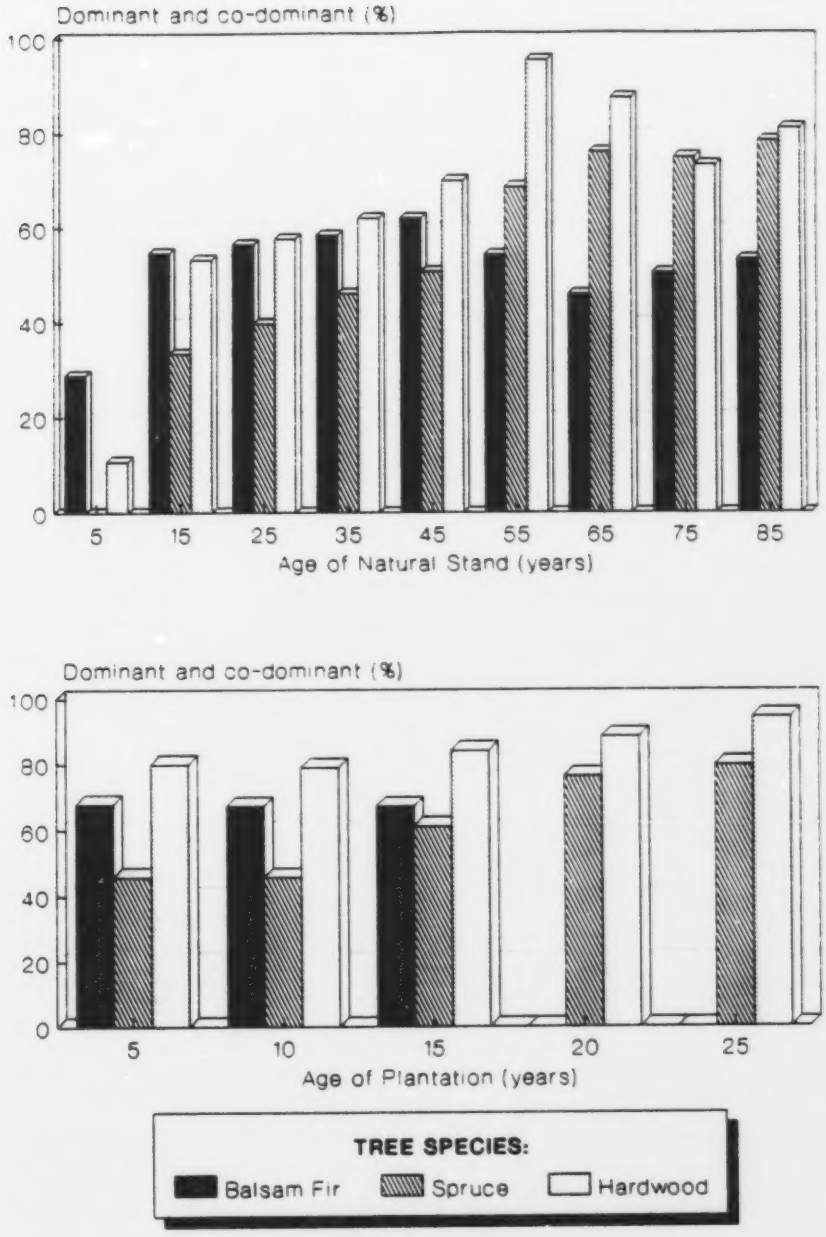

Figure 2. Comparison of species distribution throughout the canopy for natural mixedwood stands with plantations established on mixedwood sites.

Once the pathological rotation of aspen is reached at age 55-60 (Fowells, 1965), a few dominants/co-dominants begin to drop out of the stand (Figure 2). These deletions of large trees may cause minor influxes of aspen suckers, as well as releasing suppressed spruce and fir. This process has been term **Gap Phase Replacement** (Bray, 1956).

Plantation Development

A consistent feature of plantation development is the presence of the small component of advanced balsam fir regeneration. The trees that are present have poor quality due to mechanical harvesting and site preparation methods currently being used. These trees drop out of the plantation by year 20 (Figure 1).

As with the natural stand, approximately 3,000 stems/ha of hardwood tree species are present by year 5. The mortality rate, after year 10, is extremely high and the number of stem/ha drops to under 900 stems/ha by the 25th year. Virtually all of the remaining hardwood stems are dominants/co-dominants (Figure 2) and, therefore, should remain as part of the developing stand.

The other characteristic of any spruce plantation is the inflated numbers of spruce seedlings during the early stages of development, due to artificial regeneration. Initially, only 43% of the spruce were classed as dominants/co-dominants (mainly co-dominants). By year 25, 80% of the surviving spruce are in the overstory (Figure 2). The majority of the suppressed spruce die as a result of intense competition with the hardwood and shrub component present on these young plantations.

Natural versus Artificial

Three major differences in the species composition between natural stands and plantations exists up to age 25. These differences include:

(1) total number of stems/ha,
(2) the mortality rates, and
(3) the balsam fir component of the stands.

At age 5, both stands have over 6,000 stems/ha. By age 25, however, the natural stand still has over 5,400 stems/ha, but the plantation has dropped dramatically to 2,600 stems/ha. This large drop represents intense competition both within and between species. The greatest competition occurs between hardwood root suckers (intra-clonal) forcing the downward trend in numbers from 3,200 stems/ha to 900 stems/ha (Figure 1).

The natural stand has a large component of advanced regeneration. Once released, large numbers (mainly balsam fir) succumb to intensified light regimes. However, many stems survive and remain as a significant part of the developing stand. On the other hand, virtually no advanced regeneration survives past the age of 15-20 on the plantations. This difference is related to mechanical harvesting and site preparation operations which destroy or seriously damage much of the advance regeneration.

STAND STRUCTURE

Natural Stand Development

By age 5, dominance is attained by the hardwood component (58%), due to an early surge of height growth. This dominance is quickly replaced by the balsam fir advance regeneration which makes up almost 70% of the overstory by age 15 (Lyon, 1974). However, this percentage decreases systematically until

at age 35 it declines to 21% (Figure 3). A resurgence of balsam fir occurs by age 65 as some suppressed trees begin to be released during gap-phase replacement caused by mortality of a few randomly distributed dominant hardwoods.

The spruce component steadily increases until age 35-40, but lower height increments put the spruce at a height disadvantage. This results in the spruce making up only 15% of the dominant/co-dominant class by age 85 (Figure 3).

Plantation Development

The hardwood component represents over 60% of the dominant/co-dominant class by age 10. However, due to consistently higher relative growth rates of the planted spruce (Figure 5), the dominant role of the hardwood is relinquished to the spruce by year 20.

Natural versus Artificial

Three major differences in the stand structure between natural stands and plantations exists up to age 25. These differences include:

(1) presence of balsam fir in the overstory,
(2) importance of spruce in the overstory, and
(3) canopy distribution.

The release of balsam fir seedlings in the natural stands make it an important component of the overstory during the first 25 years of stand development. However, intense mechanical scarification destroys a large majority of the balsam fir present before planting. Balsam fir never makes up more than 10% of the overstory in the plantations studied (Figure 3).

Both the natural stand and the plantation exhibit similar trends in the increase of spruce in the overstory. However, the plantation's overstory is

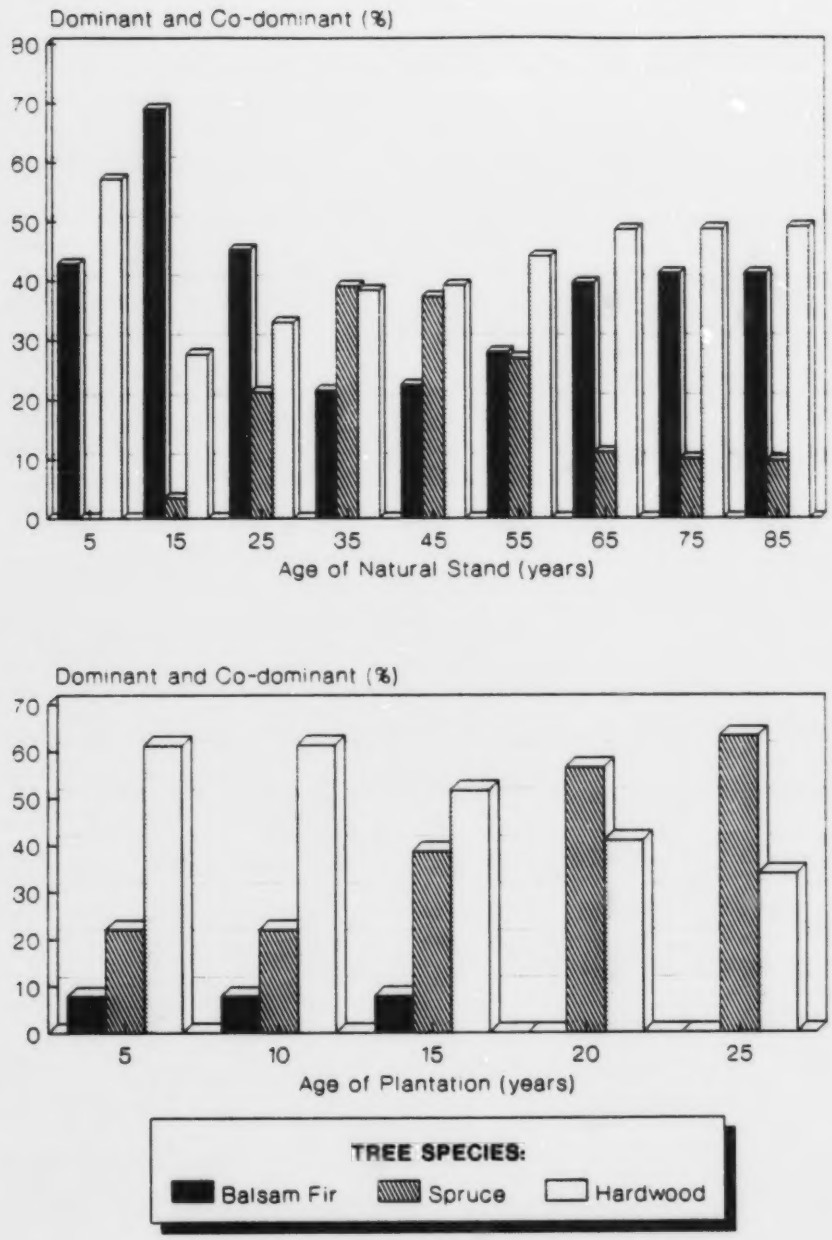

Figure 3. Comparison of stand structure for natural mixedwood stands with plantations established on mixedwood sites.

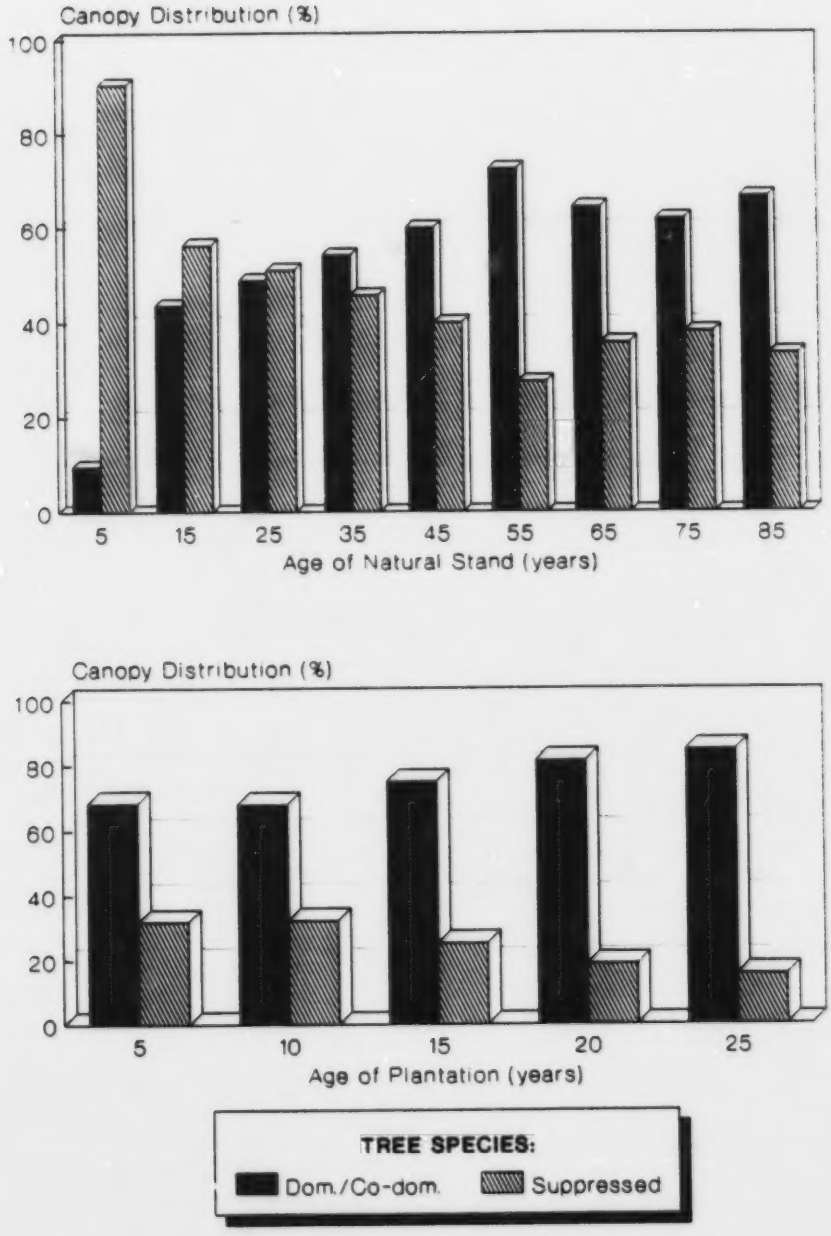

Figure 4. Comparison of canopy structure for natural mixedwood stands with plantations established on mixedwood sites.

comprised of over 60% spruce by age 25. The natural stand peaks at age 35 at under 40% (Figure 3). The majority of the spruce in natural stands is "recruited" after age 15 (Figure 1). Therefore, these seedlings are already at a significant disadvantage and, although they have comparable relative height growth rates (Figure 5), they never become dominant and begin to fall out of the stand by age 45.

Figure 4 illustrates that the natural stand is comprised mainly of suppressed stems up to age 35 and always maintains a high component throughout its development (slightly under 40%). This is, in part, a function of having a large component of tolerant balsam fir present within the stand makeup. The plantation, on the other hand, has very low numbers of suppressed stems due to the intense competition exhibited between relatively intolerant species.

GROWTH RATE

Natural Stand Development

There is a general decrease over time in relative height growth rate up to age 65. Afterwards, slight increases occur as mortality of less vigorous trees proceeds.

The stem volume increment does show a marked increase over time. By age 45, the dominants have become established and, although their relative height growth rates have dropped off (Figure 5), diameter increment is increased causing a net increase in individual tree volume (Figure 6). The balsam fir component of the stand does not contribute much to the stand volume increment as its growth is marginal. The spruce shows a gradual increase of approximately 5 times the volume from year 35 to year 60. The hardwood

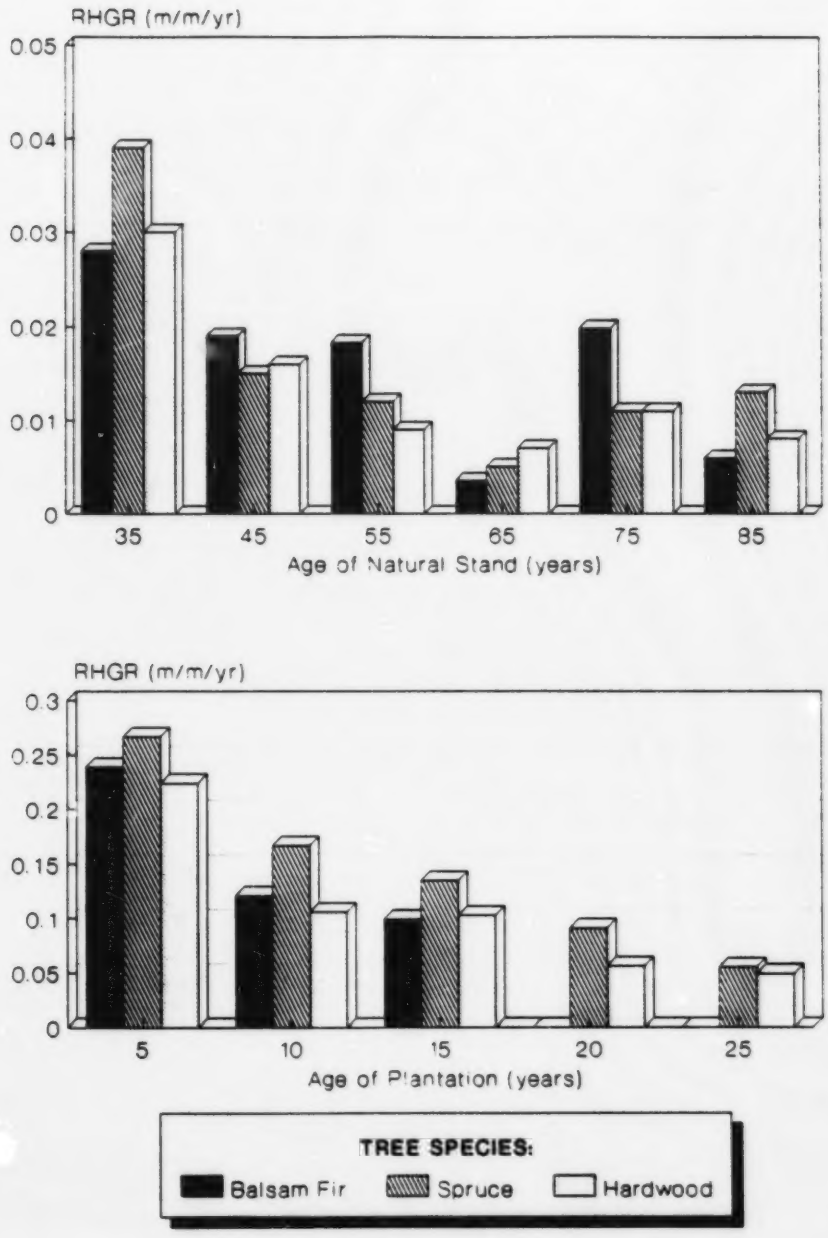

Figure 5. Comparison of relative height growth rates (dominants only) for natural mixedwood stands and plantations established on mixedwood sites.

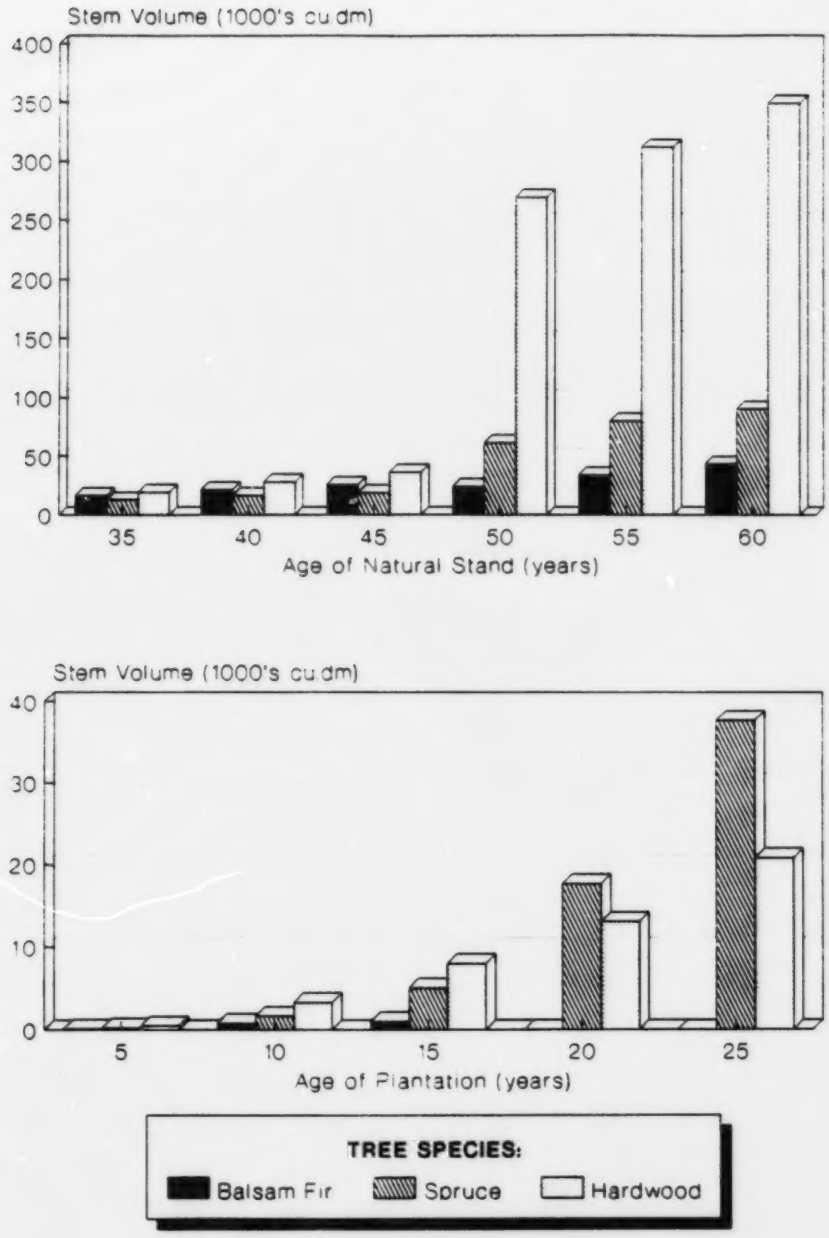

Figure 6. Comparison of stem volume increments (dominants only) for natural mixedwood stands and plantations established on mixedwood sites.

component of the stand is by far the major contributor to the overall stand volume. The dominant aspen, although having reduced **RHGR**, illustrates a logarithmic increase in volume growth with a major inflection at age 45-50 (Figure 6). The hardwood increases 17 fold from year 35 to 60. It must be noted, however, that these data are from different stands. Therefore, this volume increase may be exaggerated.

Plantation Development

Although the spruce has a slightly higher **RHGR**, by year 25, it has decreased more rapidly than the hardwood and may be overtaken in the years to come (Figure 5).

The spruce, although having a comparably lower volume by age 10, demonstrate an exponential increase up to year 25 and becomes the prime contributor to overall stand volume (Figure 6).

The hardwood component, on the other hand, demonstrates a steady, linear volume increment. Therefore, the hardwood volume increment is beginning to lag behind that of the spruce.

Natural versus Artificial

There are two major differences in growth rates between natural stands and plantations by age 25. These differences are:

(1) varying relative height growth rates, and
(2) total volume increment.

The plantations generally have lower relative growth rates than those associated with natural stands. Even the **RHGR** at age 5 for the plantation is lower than the **RHGR** at year 35 for the natural stand (Figure 5). This lower

rate is related to the more intensive competition associated with the plantation.

Although the hardwood volume seems comparable between the plantation and natural stand, the spruce volume at age 25 on the plantation is already greater than that of the natural stand at age 35 (Figure 6). Furthermore, the overall stand volume for the plantation at age 25 is approximately equal to that of the natural stand at age 35.

GENERAL DISCUSSION AND MANAGEMENT IMPLICATIONS

The forest tree owes its appearance, rate of growth, and size, in part, to the environment in which it has grown throughout its life. Put in modern biological terms, the **phenotype**, the individual as it appears, is the product of the effect of the environment on its **genotype**, its individual heredity constitution (Spurr and Barnes, 1980). The degree to which a character of a given genotype can be modified by environmental conditions is termed its plasticity or, in general, **plasticity of the phenotype** (Bradshaw, 1965). This plasticity can greatly affect the species composition, stand structure, and growth of any forest stand. The understanding of this basic ecological concept is essential when interpreting data collected from different stands. Such is the case with this study. Therefore, one should concentrate on the general trends of stand development and growth, rather than dealing with strictly absolute values. These may be difficult to interpret as you move across a gradient of sites.

Comparison of the natural mixedwood stands and plantations established on mixedwood sites identify a number of differences in stand development which represent important management considerations of these stands.

The first, and probably the most obvious difference, is the lack of advanced balsam fir regeneration present in adequately site prepared plantations. This is a positive note to current cut and skid harvesting and mechanical site preparation techniques. Mature balsam fir is particularly susceptible to spruce budworm damage and eventual mortality (Rose and Linquist, 1977). The removal of the balsam fir component from any forest stand dramatically reduces the risk of spruce budworm infestation and subsequent wildfires. Additionally, since the number of hardwood suckers tends to be similar for both the natural stands and plantations, the removal of balsam fir and planting of spruce seems to ensure a better spruce component in the developing stand. This translates to an eventual richer harvest of spruce from these successful plantations. Unfortunately, mechanical scarification tends to increase suckering to as high as 10,000 stems per hectare on those sites which had vigorous mature aspen before cutting (Zillgitt, 1951; Stoeckeler and Macon, 1956).

On the negative side, plantations have more intensive competition both within and between species, resulting in greater mortality rates and lower relative height growth rates for the planted spruce. This is partially compensated for by greater individual tree volumes. Although the hardwood mortality is extremely high, the elimination of this component of the stand at an earlier age than 15 years should not only increase the survival of the planted stock, but also should increase the volume increment potential of the

remaining spruce seedlings. The spruce volume increment currently becomes a significant portion of the overall stand volume at age 15-20. Reduction of this "lag-time" could significantly decrease the rotation age of the crop species.

With the increasing level of intensive forest management in the Boreal Mixedwood Forest of Northern Ontario, the development of a mixedwood forest growth model would greatly assist decision-making by foresters. The basic knowledge of boreal mixedwood dynamics gained from our work represents the first step in the development of such a forest growth model. Growth models often use current stand growth and stand dynamics information to predict species mix, number of stems, tree heights, tree diameters, and stand volumes of the future forest (Landsberg and McMurtrie, 1985). Foresters, with the use of models, become forecasters and will use growth models to evaluate combinations of silvicultural treatments that will best meet the objectives for which the forest area is to be managed. Forest areas to be managed can be individual stands, in which case the detail needed about each stand is not likely to be great, broad regional or national planning situations where detailed information on an individual stand basis is not needed (Burkhart, 1977). Silvicultural treatments which can be evaluated include method of harvest, site preparation, species and stock selection, initial spacing, and intermediate cultural practices such as pest control and thinning.

In 1960, Canada's first-generation growth models consisted of normal yield tables which gave graphical descriptions of stand development parameters such as mean height, mean diameter, basal area, number of trees and stand volume. These yield tables, although useful in predicting site quality, fall

short in predicting how parameters such as competition, thinning, and insect attack affect the future growth of the stand.

Later, in the 1960's, with the introduction of computers, more comprehensive field data and advanced statistical knowledge, second-generation computer simulation models appeared in the literature. Munro (1973) divided Forest Modelling into three broad philosophies:

(1) Distance dependent single tree stand models;
(2) Distance independent single tree stand models; and
(3) Distance independent whole stand models.

Silviculturalists of the Northern Rocky Mountain forests have found the "Prognosis Model" for stand development a useful tool for comparing different management treatments (Wykoff et al., 1982). The Prognosis Model, like other base models of the lake States (GROW, STEMS, LSTWIGS), can be enhanced using submodels to provide flexibility when dealing with specialized activities which make up the management regime. These include specific pest control, water and wildlife management, economic and recreational activities.

Due to the diversity of the boreal mixedwood forest, the development of a new forest growth model specific for Northern Ontario would take a team of scientists several man-years. A more viable option would be to test and modify, using our current knowledge of mixedwood dynamics, existing models developed in other regions.

LITERATURE CITED

Bradshaw, A.D. 1965. Evolutionary significance of phenotypic plasticity in plants. Adv. Genetics 13:115-155.

Bray, J.R. 1956. Gap phase replacement in a maple/basswood forest. Ecology 37:598-600.

Burkhart, H.E. 1977. Stand modelling for radiata pine in New Zealand. J. For. 22:297-307.

Dixon, R.M. 1963. The forest resources of Ontario. Ont. Dept. Lands and For., Timber Br., Toronto, Ont. 108 p.

Fowells, H.A. 1965. Silvics of forest trees of the United States. USDA, For. Serv. Agricultural Handbook No. 271, Washington, D.C. 762 p.

Ketcheson, D.E. 1981. Some thought on the economics of boreal mixedwood management. p. 17-20. In: R.D. Whitney and K.M. McClain (eds.) Boreal Mixedwood Symposium, COJFRC Symposium Proceedings O-P-9. 278 p.

Landsberg, J.J. and R. McMurtrie. 1985. Models based on physiology as tools for research and forest management. p. 214-228. In: J.J. Landsberg (ed.) Research for Forest Management Melbourne, Australia.

McClain, K.M. 1981. Definition and distribution of the boreal mixedwood forest in Ontario. p. 5-9. In: R.D. Whitney and K.M. McClain (eds.) Boreal Mixedwood Symposium, COJFRC Symposium Proceedings O-P-9. 278 p.

Munro, D.D. 1974. Forest growth models - a prognosis. In: J. Fries (ed.) Growth Models for Tree and Stand Simulation. Royal College of Forestry, Stockholm, Sweden.

Rose, A.H. and O.H. Lindquist. 1977. Insects of eastern spruces, fir and hemlock. Dept. Environ., Can. for. Serv., For. Tech. Report 23. 159 p.

Sims, R.A., W.D. Towill, K.A. Baldwin, and G.M. Wickware. 1987. Field guide to forest ecosystem classification for the North Central Region, Site Regions 3W and 4W. Queen's Printer for Ontario, Toronto.

Stoeckeler, J.H. and J.W. Macon. 1956. Regeneration of aspen cutover areas in northern Wisconsin. J. For. 54:13-16.

Weingartner, D.H. and J.T. Basham (eds.). 1979. Forest management and research needs in the boreal mixedwood forest of Ontario. File Report prepared by the Spruce-Fir-Aspen Forest Research Committee, COJRFC. 90 p. (Unpubl.)

Wykoff, W.R., N.L. Crookston, and A.R. Stage. 1982. User's guide to the stand prognosis mode. USDA For. Serv. INT-133, Intermountain Forest and Range Experiment Station. 112 p.

Zillgitt, W.M. 1951. Disking to increase stocking in aspen stands. U.S. For. Serv., Lake States Forest Expt. Sta., Tech. Note 357. 1 p.